FORM PTO-1390 (REV. 5-93) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10191/2225
	Rec'd PCT/PTO 15 MAR 2002
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S APPLICATION NO (If known, see 37 CFR 1.5) 10/088240

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE(S) CLAIMED
PCT/DE00/03194	(14.09.00) 14 September 2000	(15 09 99) 15 September 1999

TITLE OF INVENTION
ELECTRONICALLY COMMUTATABLE MOTOR

APPLICANT(S) FOR DO/EO/US

Joerg SUTTER; Wolfgang SCHWENK, and Claude BERLING

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U S C 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau)
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2))
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U S C 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording A separate cover sheet in compliance with 37 CFR 3 28 and 3 31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification and a marked up version thereof
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information International Search Report; International Preliminary Examination Report; and Form PCT/RO/101. (English Translations)

Express Mail No.

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U.S. APPLICATION NO (if known, see 37 C.F.R.1.5	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
[illegible]	PCT/DE00/03194	10191/2225

17. ☒ The following fees are submitted

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $890.00 International preliminary examination fee paid to USPTO (37 CFR 1 482) . $740.00 No international preliminary examination fee paid to USPTO (37 CFR 1 482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) . ... $710 00 Neither international preliminary examination fee (37 CFR 1 482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .. . . $1,040 00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100 00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	8 - 20 =	0	X $18.00	$ 0	
Independent Claims	1 - 3 =	0	X $84 00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $270.00	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 890	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28)	$	
SUBTOTAL =	$ 890	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 890	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 890	
	Amount to be: refunded	$
	charged	$

a. ☐ A check in the amount of $____________________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$890.00** to cover the above fees A duplicate copy of this sheet is enclosed

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1 495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO.

By: [signature] Reg No 35,952

SIGNATURE

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3/15/02
DATE

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[10191/2225]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	Joerg SUTTER et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	ELECTRONICALLY COMMUTATABLE MOTOR
Art Unit	:	To Be Assigned
Examiner	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend without prejudice the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

Without prejudice, please cancel original claims 1 to 8. Please also cancel claim 1 in the annex to the International Preliminary Examination Report, and add new claims 9 to 16 as follows:

9. (New) An electronically commutatable motor having excitation windings, comprising:
at least one semiconductor output stage;

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an electronic control unit controlling the excitation windings via the at least one semiconductor output stage by emitting control signals corresponding to an adjustable control signal and a setpoint value, the electronic control unit further storing a motor characteristic curve from which an assigned nominal operating speed is derivable for the setpoint value, the derived nominal operating speed being comparable to an actual speed of the motor;

wherein, if a predefined speed difference between the nominal operating speed and the actual speed is exceeded, at least one of the electronic control unit and the at least one semiconductor output stage can be switched off, and

wherein the motor characteristic curve is stored as a characteristics field having four three-dimensional corner points, each representing operating speeds of a characteristics field for a predefined, constant load, the corner points being determined by limiting values of the supply voltage and limiting values of the control signals, lines connecting the four corner points of the characteristics field permitting formation of a grid, from which, for an existing supply voltage and a control signal corresponding to the predefined setpoint value, the nominal operating speed is derivable from comparison to the measured actual speed.

10. (New) The electronically commutatable motor of claim 9, wherein comparison between the nominal operating speed and the actual speed is carried in one of the following ways:

i) continually during a continuous operation of the motor; and

ii) repeated at time intervals.

11. (New) The electronically commutatable motor of claim 9, wherein the setpoint value is manually adjusted using a potentiometer.

12. (New) The electronically commutatable motor of claim 9, wherein, for comparison of the nominal operating speed and the actual speed, the electronic control unit is coupled to a comparator unit.

13. (New) The electronically commutatable motor of claim 9, wherein the comparator unit is integrated into the electronic control unit.

14. (New) The electronically commutatable motor of claim 9, wherein the switching off of the at least one of the electronic control unit and the at least one semiconductor output stage is carried out in a time-delayed manner.

15. (New) The electronically commutatable motor of claim 9, wherein comparison of the nominal operating speed and the actual speed is initiated and carried out only after a run-up phase of a predefined duration has expired.

16. (New) The electronically commutatable motor of claim 15, wherein the run-up phase can be initiated with a switching-on of at least one of the electronic control unit, the at least one semiconductor output stage, and the input of a setpoint value.

REMARKS

This Preliminary Amendment cancels without prejudice original claims 1 to 8 and claim 1 in the annex to the International Preliminary Examination Report, in the underlying PCT Application No. PCT/DE00/03194, and adds without prejudice new claims 9 to 16. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules, to correct informalities and to include Substitute Pages in the annex of the International Preliminary Examination Report. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/03194 includes an International Search Report, dated February 5, 2001. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT application also includes an International Preliminary Examination Report, dated November 26, 2001, and an annex. An English translation of the International Preliminary Examination Report and the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON By: [signature] Reg No 35,982

Dated: 3/15/02

By: [signature]
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[10191/2225]

ELECTRONICALLY COMMUTATABLE MOTOR

Field Of The Invention

The present invention relates to an electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals. A setpoint value can be specified to the control unit, and the control unit emits corresponding PWM control signals to the semiconductor output stages. A motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value is stored in the control unit, and the derived nominal operating speed can be compared to the actual speed of the motor. If a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages can be switched off.

Background Information

A conventional electronically commutatable motor is described in German Published Patent Application 198 04 874. In that case, the PWM control signals are established in their pulse width by the input of the setpoint value. The comparison of the nominal operating speed, which is assigned to the setpoint value, to the actual speed, is used during the continuous running operation for detecting sharp increases of the setpoint value acting from outside, in order to set the pulse width only gradually to the new value. Since the motor characteristic curve changes as a function of the motor load and the setpoint value, it requires a considerable expenditure of memory in the control unit to ascertain the allocated nominal operating speed.

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Storage of the characteristic-curve data of a motor in a memory of the control unit and use of the characteristic-curve data for deriving an operating value is discussed to some extent in the U.S. Patent No. 5,901,286 and European Published Patent Application No. 0 886 057. In these references, a characteristics field having a plurality of value pairs is used, from which the desired nominal operating value can be derived by interpolation onto a third coordinate. However, this requires a considerable expenditure of memory, particularly when the load of the motor changes.

The object of the present invention is to provide a motor of the type mentioned at the outset with simple data in the control unit, which, with minimal expenditure, for a predefined load, significantly simplifies the derivation of the nominal operating speed corresponding to a predefined setpoint value.

Summary Of The Invention

According to the present invention, this objective is achieved by storing the motor characteristic curve only as a three-dimensional characteristics field having four corner points, which, through coordination with the smallest pulse width and the limiting values of the supply voltage, as well as with the largest pulse width and the limiting values of the supply voltage, are determined by the nominal operating speeds assigned in each case. The nominal operating speed for the comparison to the actual speed is derivable as a function of the existing supply voltage, the predefined setpoint value and the stored coordinate values of the characteristics field.

In this context, advantage is taken of the fact that in many cases, the motor is always loaded with the same consumer, such as in the case of a fan drive. The four

coordinate values of the characteristics field take into account not only the pulse widths of the PWM control signals corresponding to the predefinable setpoint values, but also the fluctuations of the supply voltage, and define a characteristics field which allows a clear and simple derivation, i.e. calculation of the assigned nominal operating speed, for the supply voltage present in each case and the control conditions, the connecting lines of the corner points of the characteristics field giving the stipulations for a grid, and thus facilitating the derivation of intermediate values in the coordinate directions for the supply voltage (e.g. x-coordinate) and the pulse widths (e.g. z-direction), and leading to the sought nominal operating speed (in the y-direction).

Depending upon the use of the motor, according to a further embodiment, the four corner points of the characteristics field may be determined for a predefined motor load. The motor can then be designed in a simple manner for a different load, i.e. consumer.

In this context, according to one refinement of the present invention, the comparison between the nominal operating speed and the actual speed is able to be carried out continually during the continuous running of the motor or repeated at time intervals.

The setpoint value may be specifiable manually in a simple manner using a potentiometer, the control unit being able to be supplied with a variable setting signal which is used for the emission of allocated PWM control signals for the semiconductor output stages. In addition, using this setting signal, the allocated nominal operating speed may be derived on the basis of the stored motor characteristic curve and utilized for the comparison with the actual speed of the motor arising. The actual speed of the motor may be detected in various

different ways.

For the comparison of the nominal operating speed and the actual speed, the control unit is coupled to a comparator unit which may be integrated into the control unit.

So that the overload protection does not react to short interference pulses of the actual-speed measurement, one embodiment of the present invention provides for the control unit and/or the semiconductor output stages to be switched off in a time-delayed manner.

If a run-up phase precedes the continuous operation of the motor, then the overload protection may be designed so that the comparison of the nominal operating speed and the actual speed is first able to be initiated and carried out after a run-up phase of a predefined duration has expired, so that an inadvertent shut-down does not occur during this operating phase. The run-up phase may be preset by the control unit, and the amplitude of the pulses and the pulse width of the PWM control signals, as well as their commutation frequency may be used as parameters. The run-up phase of the motor is able to be initiated with the switch-on of the control unit and/or the semiconductor output stages, and/or the input of a setpoint value for the control unit.

Brief Description Of The Drawings

Figure 1 shows a block diagram of the functional units of an exemplary motor according to an embodiment of the present invention.

Figure 2 shows a characteristics field stored in the control unit according to an embodiment of the present invention.

Detailed Description

As the block diagram according to Figure 1 shows, the motor unit includes an electronic control unit STE which is assigned a comparator unit VE. For a desired continuous operation, a correspondingly adjusted setpoint value $N_{setpointv}$ is specified and provided to this control unit STE. Consequently, after a run-up phase, correspondingly dimensioned PWM control signals pwm are emitted to semiconductor output stages EST which energize the excitation windings of motor M according to the pulse widths of these PWM control signals pwm. An actual speed N_{actual} thereupon sets in at motor M that is detected and supplied as a signal to a comparator unit VE which may be integrated into control unit STE. Control unit STE stores a motor characteristic curve which allows the derivation of a nominal operating speed n_x for each setpoint value $N_{setpointv}$. This nominal operating speed n_x is obtained more or less exactly in the case of the predefined setpoint value $N_{setpointv}$ if control unit STE, semiconductor output stages EST and motor M are operating correctly, and no conditions exist which lead to a drop in actual speed N_{actual}.

Nominal operating speed n_x, like actual speed N_{actual}, is supplied to comparator unit VE, and a speed deviation ΔN is ascertained. If actual speed N_{actual} is more than a predefined or predefinable speed deviation ΔN below expected nominal operating speed n_x, then a fault exists which can lead to an overload during continuous operation. Therefore, comparator unit VE generates a switch-off signal AB via which control unit STE and/or semiconductor output stages EST can be switched off, as the contacts AB off in the electric circuit of supply voltage U_{batt} indicate.

If setpoint value $N_{setpointv}$ is changed, then PWM control signals pwm, and therefore actual speed N_{actual} of motor M change, as well. A correspondingly new nominal operating

speed n_x is supplied to comparator unit VE, and the comparison is carried out in the same manner for the new continuous operation with altered speed.

The switch-off of control unit STE and/or of semiconductor output stages EST may also be initiated in a delayed fashion, in order to suppress spurious peaks in the derived and detected speed values.

Permissible speed deviation ΔN may also be made a function of the magnitude of predefined setpoint value $N_{setpointv}$ and the existing magnitude of supply voltage u_x. The comparison by comparator unit VE may be carried out continually during the continuous operation, or repeated at time intervals. In addition, the overload protection by the comparison and the shutdown may first be switched to effective after reaching the nominal operating speed specified by the setpoint value, i.e. after a predefined or predefinable run-up time has expired. In this context, the run-up time may be started with the switching-on, that is to say, with the feeding of supply voltage u_x to control circuit STE and/or to semiconductor output stages EST, and/or with the application of a predefined setpoint value $N_{setpointv}$ to control unit STE.

Nominal operating speed n_x, derived and calculated by control unit STE, is a function not only of existing supply voltage u_x with its limiting values u_1 and u_2, but also of stored speeds n_{11}, n_{12}, n_{21}, n_{22} of the corner points of characteristics field KF, as the specification $n_x=f(N_{setpointv}, u_1, u_2, n_{11}, n_{12}, n_{21}, n_{22})$ in the Figure indicates, and as is clarified later.

As the three-dimensional characteristics field KF according to Figure 2 shows, the voltage range from U_{max} to U_{min} is plotted in the x-direction, while the pulse width from pwm_{min} to pwm_{max} extends in the z-direction. In

the exemplary embodiment, U_{max} = 13V and U_{min} = 8V are selected, and the pulse width has a range from pwm_{min} = 60% to pwm_{max} = 100%. For the smallest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds of n_{11} = 50 min^{-1} and n_{21} = 1800 mm^{-1} result, while for the greatest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds n_{12} = 150 min^{-1} and n_{22} = 2900 min^{-1} result. These nominal operating speeds n_{11} to n_{22} define the four corner points P1 to P4 in three-dimensional characteristics field KF. The connecting lines between corner points n_{11} and n_{21}, n_{11} and n_{12}, n_{21} and n_{22}, and n_{12} and n_{22}, respectively, permit the formation of a grid which, for existing supply voltages U_x and pulse width pwm_x corresponds to a setpoint value. Formation of the grid allows the derivation of allocated nominal operating speeds n_x on straight line $n1_x$ - $n2_x$. Thus, given a supply voltage of U_x = 10.5V and a pulse width of approximately 87%, a nominal operating speed of approximately 1800 min^{-1} can be interpolated from characteristics field KF.

This characteristics field KF is valid for a specific motor for a predefined, constant load. For a further load, a characteristics field KF valid for the further load can be stored in control unit STE.

As the three-dimensional characteristics field KF according to Figure 2 shows, supply voltage u_x having the voltage range from smallest supply voltage u_1 = 8V to greatest supply voltage u_2 = 13V is plotted in the x-direction. In the z-direction, pulse width pwm of the PWM control signals is predefined, which may extend from minimal pulse width pwm_1 = 60% to maximum pulse width pwm_2 = 100%. Given a preselected load of the motor, four limit operation cases are ascertained with u_1 and pwm_1, u_1 and pwm_2, u_2 and pwm_1, as well as u_2 and pwm_2, which lead to nominal operating speeds n_x = n_1, n_{12}, n_{21} and n_{22}, and

consequently define characteristics field KF according to Figure 2.

If motor M is loaded with a different load, then a similar characteristics field KF results having new nominal operating speeds n_{11}, n_{12}, n_{21} and n_{22}.

The following values result for characteristics field KF of an exemplary embodiment shown in Figure 2:

n_{11} = 50 min^{-1} at u_1 = 8V and pwm_1 = 60 %
n_{12} = 150 min^{-1} at u_2 = 13V and pwm_1 = 60 %
n_{21} = 1800 min^{-1} at u_1 = 8V and pwm_2 = 100 %
n_{22} = 2900 min^{-1} at u_2 = 13V and pwm_2 = 100 %

Characteristics field KF can be represented as a grid, the connecting lines between corner points n_{11} and n_{12}, and n_{21} and n_{22}, respectively, as well as n_{11} and n_{22}, and n_{12} and n_{22}, respectively, specifying the gridding, and as is shown, for an existing supply voltage u_x, permitting the derivation of allocated nominal operating speed n_x in the case of existing PWM control signal p_x. PWM control signal pwm_x is allocated to predefined setpoint value $N_{setpointv}$.

As grid line nx_1 - nx_2 shows, in the case of u_x = 10.5V and a pulse width of $pwm_x \approx 87.5\%$, the derivation of nominal operating speed n_x leads to a value of approximately 1800 min^{-1}.

To calculate nominal operating speed n_x allocated to a setpoint value $N_{setpointv}$, one proceeds as follows with interpolated coefficients stg1, stg2 and stg3:

$$stg1 = \frac{n_{12} - n_{11}}{u_2 - u_1} \qquad stg2 = \frac{n_{22} - n_{21}}{u_2 - u_1}$$

$$n_{1x} = n_{11} + stg_1 * (u_x - u_1)$$
$$n_{2x} = n_{21} + stg_2 * (u_x - u_1)$$

$$stg_3 = \frac{n_{2x} - n_{1x}}{pwm_2 - pwm_1} = \frac{n_{21} - n_{11} + (stg_2 - stg_1) * (u_x - u_1)}{pwm_2 - pwm_1}$$

Thus,

$$\boxed{n_x = n_{1x} + stg_3 * (pwm_x - pwm_1)}$$

Since the calculations use the reciprocal of the speed values, the above equation for calculating surface point n_x must be changed around accordingly. With $T_x = a/n_x$, it follows that:

$$\frac{a}{T_x} = n_{1x} + stg_3 * (pwm_x - pwm_1)$$

$$T_x = \frac{a * (pwm_1 - pwm_2)}{(((stg_1 - stg_2) * u_x - n_{21} + n_{11} + (stg_2 - stg_1) * u_1) * pwm_x + (pwm_1 * stg_2 - pwm_2 * stg_1) * u_x + pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u}$$

In the formula above, only supply voltage U_x and the pulse

width of output-stage control pwm_x are variable. The remaining factors may be stored as fixed parameters in the ROM or EEPROM. Following is once again the same formula with the variable names used in the program code.

$$\boxed{v\_tx = \frac{K\_ZAEHL_1}{\left(\left(K\_NENN_1 * v\_ubat + K\_NENN_2\right) * v\_pwm\_endst + K\_NENN_3 * v\_ubat + K\_NENN_4\right)}}$$

During the programming at the rear end of the assembly line, the corresponding parameters can now be transferred from the test stand into the EEPROM of the motor control.

Wherein:

$$K\_NENN_1 = \left(stg_1 - stg_2\right)$$

$$K\_NENN_2 = -n_{21} + n_{11} + \left(stg_2 - stg_1\right) * u_1$$

$$K\_NENN_3 = \left(pwm_1 * stg_2 - pwm_2 * stg_1\right)$$

$$K\_NENN_4 = pwm_1 * \left(n_{21} - u_1 * stg_2\right) + pwm_2 * \left(stg_1 * u_1 - n_{11}\right)$$

Abstract Of The Disclosure

An electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals, a setpoint value being specifiable to the control unit, and the control unit emitting corresponding PWM control signals to the semiconductor output stages; a motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value being stored in the control unit, and the derived nominal operating speed being able to be compared to the actual speed of the motor. If a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages can be switched off. The derivation of the nominal operating speed for the predefined setpoint value is facilitated by a three-dimensional characteristics field determined by four coordinate points.

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[10191/2225]

ELECTRONICALLY COMMUTATABLE MOTOR

[Background Information] Field Of The Invention

The present invention relates to an electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals[, a]. A setpoint value [being specifiable] can be specified to the control unit, and the control unit [emitting] emits corresponding PWM control signals to the semiconductor output stages[; a]. A motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value[, being] is stored in the control unit, and the derived nominal operating speed [being able to] can be compared to the actual speed of the motor[, and if]. If a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages [is/are able to be switched off.] can be switched off.

[Such a motor is known from the German Patent]Background Information

A conventional electronically commutatable motor is described in German Published Patent Application 198 04 874 [A1]. In that case, the PWM control signals are established in their pulse width by the input of the setpoint value. The comparison of the nominal operating speed, which is assigned to the setpoint value, to the actual speed, is used during the continuous running operation for detecting sharp increases of the setpoint value acting from outside, in order to set the pulse width only gradually to the new value. Since the motor characteristic curve changes as a function of the motor load and the setpoint value, it requires a considerable

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expenditure of memory in the control unit to ascertain the allocated nominal operating speed.

Storage of the characteristic-curve data of a motor in a memory of the control unit and use of the characteristic-curve data for deriving an operating value is discussed to some extent in the U.S. Patent No. 5,901,286 and European Published Patent Application No. 0 886 057. In these references, a characteristics field having a plurality of value pairs is used, from which the desired nominal operating value can be derived by interpolation onto a third coordinate. However, this requires a considerable expenditure of memory, particularly when the load of the motor changes.

The object of the present invention is to provide a motor of the type mentioned at the outset with simple data in the control unit, which, with minimal expenditure, for a predefined load, significantly simplifies the derivation of the nominal operating speed corresponding to a predefined setpoint value.

Summary Of The Invention

According [This objective is achieved according] to the present invention [in that], this objective is achieved by storing the motor characteristic curve [is stored] only as a three-dimensional characteristics field having four corner points, which, through coordination with the smallest pulse width and the limiting values of the supply voltage, as well as with the largest pulse width and the limiting values of the supply voltage, are determined by the nominal operating speeds assigned in each case[, and that the]. The nominal operating speed for the comparison to the actual speed is derivable as a function of the existing supply voltage, the predefined setpoint value and the stored coordinate values of the

characteristics field.

In this context, advantage is taken of the fact that in many cases, the motor is always loaded with the same consumer, such as in the case of a fan drive. The four coordinate values of the characteristics field take into account not only the pulse widths of the PWM control signals corresponding to the predefinable setpoint values, but also the fluctuations of the supply voltage, and define a characteristics field which allows a clear and simple derivation, i.e. calculation of the assigned nominal operating speed, for the supply voltage present in each case and the control conditions, the connecting lines of the corner points of the characteristics field giving the stipulations for a grid, and thus facilitating the derivation of intermediate values in the coordinate directions for the supply voltage (e.g. x-coordinate) and the pulse widths (e.g. z-direction), and leading to the sought nominal operating speed (in the y-direction).

Depending upon the use of the motor, according to a further embodiment, the four corner points of the characteristics field may be determined for a predefined motor load. The motor can then be designed in a simple manner for a different load, i.e. consumer.

In this context, according to one refinement <u>of the present invention</u>, the comparison between the nominal operating speed and the actual speed is able to be carried out continually during the continuous running of the motor or repeated at time intervals.

The setpoint value may be specifiable manually in a simple manner using a potentiometer, the control unit being able to be supplied with a [more or less large] <u>variable</u> setting signal which is used for the emission of allocated PWM control signals for the semiconductor

output stages. In addition, using this setting signal, the allocated nominal operating speed may be derived on the basis of the stored motor characteristic curve and utilized for the comparison with the actual speed of the motor arising. The actual speed of the motor may be detected in various different ways [which are also known].

For the comparison of the nominal operating speed and the actual speed, the control unit is [preferably assigned] coupled to a comparator unit which[, by preference, is] may be integrated into the control unit.

So that the overload protection does not react to short interference pulses of the actual-speed measurement, one embodiment of the present invention provides for the control unit and/or the semiconductor output stages to be switched off in a time-delayed manner.

If a run-up phase precedes the continuous operation of the motor, then the overload protection may be designed so that the comparison of the nominal operating speed and the actual speed is first able to be initiated and carried out after a run-up phase of a predefined duration has expired, so that an inadvertent shut-down does not occur during this operating phase. The run-up phase may be preset by the control unit, [it being possible to use] and the amplitude of the pulses and the pulse width of the PWM control signals, as well as their commutation frequency [and the like] may be used as parameters. The run-up phase of the motor is able to be initiated with the switch-on of the control unit and/or the semiconductor output stages, and/or the input of a setpoint value for the control unit.

[The invention is explained more precisely with reference to an exemplary embodiment shown in the Drawing, in

which:] <u>Brief Description Of The Drawings</u>

Figure 1 shows a block diagram of the functional units of [the motor; and] <u>an exemplary motor according to an embodiment of the present invention.</u>

Figure 2 shows a characteristics field stored in the control unit <u>according to an embodiment of the present invention.</u>

<u>Detailed Description</u>

As the block diagram according to Figure 1 shows, the motor unit includes an electronic control unit STE which is assigned a comparator unit VE. For a desired continuous operation, a correspondingly adjusted setpoint value $N_{setpointv}$ is specified <u>and provided</u> to this control unit STE. Consequently, after a run-up phase, correspondingly dimensioned PWM control signals pwm are emitted to semiconductor output stages EST which energize the excitation windings of motor M according to the pulse widths of these PWM control signals pwm. An actual speed N_{actual} thereupon sets in at motor M that is detected [in a known manner] and supplied as a signal to a comparator unit VE which may be integrated into control unit STE. [Stored in control] <u>Control</u> unit STE [is] <u>stores</u> a motor characteristic curve which allows the derivation of a nominal operating speed n_x for each setpoint value $N_{setpointv}$. This nominal operating speed n_x is obtained more or less exactly in the case of the predefined setpoint value $N_{setpointv}$ if control unit STE, semiconductor output stages EST and motor M are operating correctly, and no conditions exist which lead to a drop in actual speed N_{actual}.

Nominal operating speed n_x, like actual speed N_{actual}, is supplied to comparator unit VE, and a speed deviation ΔN is ascertained. If actual speed N_{actual} is more than a predefined or predefinable speed deviation ΔN below

expected nominal operating speed n_x, then a fault exists which can lead to an overload during continuous operation. Therefore, comparator unit VE generates a switch-off signal AB [with] via which control unit STE and/or semiconductor output stages EST can be switched off, as the contacts AB off in the electric circuit of supply voltage U_{batt} indicate.

If setpoint value $N_{setpointv}$ is changed, then PWM control signals pwm, and therefore actual speed N_{actual} of motor M change, as well. A correspondingly new nominal operating speed n_x is supplied to comparator unit VE, and the comparison is carried out in the same manner for the new continuous operation with altered speed.

The switch-off of control unit STE and/or of semiconductor output stages EST may also be initiated in a delayed fashion, in order to suppress spurious peaks in the derived and detected speed values.

Permissible speed deviation ΔN may also be made a function of the magnitude of predefined setpoint value $N_{setpointv}$ and the existing magnitude of supply voltage u_x. The comparison by comparator unit VE may be carried out continually during the continuous operation, or repeated at time intervals. In addition, the overload protection by the comparison and the shutdown may first be switched to effective after reaching the nominal operating speed specified by the setpoint value, i.e. after a predefined or predefinable run-up time has expired. In this context, the run-up time may be started with the switching-on, that is to say, with the feeding of supply voltage u_x to control circuit STE and/or to semiconductor output stages EST, and/or with the application of a predefined setpoint value $N_{setpointv}$ to control unit STE.

Nominal operating speed n_x, derived and calculated by

control unit STE, is a function not only of existing supply voltage u_x with its limiting values u_1 and u_2, but also of stored speeds n_{11}, n_{12}, n_{21}, n_{22} of the corner points of characteristics field KF, as the specification $n_x=f(N_{setpointv}, u_1, u_2, n_{11}, n_{12}, n_{21}, n_{22})$ in the Figure indicates, and as is clarified later.

As the three-dimensional characteristics field KF according to Figure 2 shows, the voltage range from U_{max} to U_{min} is plotted in the x-direction, while the pulse width from pwm_{min} to pwm_{max} extends in the z-direction. In the exemplary embodiment, U_{max} = 13V and U_{min} = 8V are selected, and the pulse width has a range from pwm_{min} = 60% to pwm_{max} = 100%. For the smallest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds of n_{11} = 50 min^{-1} and n_{21} = 1800 mm^{-1} result, while for the greatest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds n_{12} = 150 min^{-1} and n_{22} = 2900 min^{-1} result. These nominal operating speeds n_{11} to n_{22} define the four corner points P1 to P4 in three-dimensional characteristics field KF. The connecting lines between corner points n_{11} and n_{21}, n_{11} and n_{12}, n_{21} and n_{22}, and n_{12} and n_{22}, respectively, permit the formation of a grid which, for existing supply voltages U_x and pulse width pwm_x [corresponding] corresponds to a setpoint value[,]. Formation of the grid allows the derivation of allocated nominal operating speeds n_x on straight line $n1_x$ - $n2_x$. Thus, given a supply voltage of U_x = 10.5V and a pulse width of approximately 87%, a nominal operating speed of approximately 1800 min^{-1} can be interpolated from characteristics field KF.

This characteristics field KF is valid for a specific motor for a predefined, constant load. For [another] a further load, a characteristics field KF valid for [it] the further load can be stored in control unit STE.

As the three-dimensional characteristics field KF according to Figure 2 shows, supply voltage u_x having the voltage range from smallest supply voltage u_1 = 8V to greatest supply voltage u_2 = 13V is plotted in the x-direction. In the z-direction, pulse width pwm of the PWM control signals is predefined, which may extend from minimal pulse width pwm_1 = 60% to maximum pulse width pwm_2 = 100%. Given a preselected load of the motor, four limit operation cases are ascertained with u_1 and pwm_1, u_1 and pwm_2, u_2 and pwm_1, as well as u_2 and pwm_2, which lead to nominal operating speeds $n_x = n_1$, n_{12}, n_{21} and n_{22}, and consequently define characteristics field KF according to Figure 2.

If motor M is loaded with a different load, then a similar characteristics field KF results having new nominal operating speeds n_{11}, n_{12}, n_{21} and n_{22}.

The following values result for characteristics field KF of an exemplary embodiment shown in Figure 2:

n_{11} = 50 min^{-1} at u_1 = 8V and pwm_1 = 60 %
n_{12} = 150 min^{-1} at u_2 = 13V and pwm_1 = 60 %
n_{21} = 1800 min^{-1} at u_1 = 8V and pwm_2 = 100 %
n_{22} = 2900 min^{-1} at u_2 = 13V and pwm_2 = 100 %

Characteristics field KF can be represented as a grid, the connecting lines between corner points n_{11} and n_{12}, and n_{21} and n_{22}, respectively, as well as n_{11} and n_{22}, and n_{12} and n_{22}, respectively, specifying the gridding, and as is shown, for an existing supply voltage u_x, permitting the derivation of allocated nominal operating speed n_x in the case of existing PWM control signal p_x. PWM control signal pwm_x is allocated to predefined setpoint value $N_{setpointv}$.

As grid line nx_1 - nx_2 shows, in the case of u_x = 10.5V and a pulse width of $pwm_x \approx 87.5\%$, the derivation of nominal operating speed n_x leads to a value of approximately 1800 min^{-1}.

To calculate nominal operating speed n_x allocated to a setpoint value $N_{setpointv}$, one proceeds as follows <u>with interpolated coefficients stg1, stg2 and stg3:</u>[:]

$$stg1 = \frac{n_{12} - n_{11}}{u_2 - u_1} \qquad stg2 = \frac{n_{22} - n_{21}}{u_2 - u_1}$$

$$n_{1x} = n_{11} + stg_1 * (u_x - u_1)$$
$$n_{2x} = n_{21} + stg_2 * (u_x - u_1)$$

$$stg_3 = \frac{n_{2x} - n_{1x}}{pwm_2 - pwm_1} = \frac{n_{21} - n_{11} + (stg_2 - stg_1) * (u_x - u_1)}{pwm_2 - pwm_1}$$

[Therein:] <u>Thus,</u>

$$\boxed{n_x = n_{1x} + stg_3 * (pwm_x - pwm_1)}$$

[stgi -
stg2 -
stgs3 -

Since computer-internally, work is not done with the

speed, but rather with its reciprocal value] Since the calculations use the reciprocal of the speed values, the above equation for calculating surface point n_x must be changed around accordingly. With $T_x = a/n_x$, it follows that:

$$\frac{a}{T_x} = n_{1x} + stg_3 * (pwm_x - pwm_1)$$

$$T_x = \frac{a * (pwm_1 - pwm_2)}{(((stg_1 - stg_2) * u_x - n_{21} + n_{11} + (stg_2 - stg_1) * u_1) * pwm_x + (pwm_1 * stg_2 - pwm_2 * stg_1) * u_x + pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u}$$

In the formula above, only supply voltage U_x and the pulse width of output-stage control pwm_x are variable. The remaining factors may be stored as fixed parameters in the ROM or EEPROM. Following is once again the same formula with the variable names used in the program code.

$$\boxed{v\_tx = \frac{K\_ZAEHL_1}{((K\_NENN_1 * v\_ubat + K\_NENN_2) * v\_pwm\_endst + K\_NENN_3 * v\_ubat + K\_NENN_4)}}$$

During the programming at the rear end of the assembly line, the corresponding parameters can now be transferred from the test stand into the EEPROM of the motor control.

Wherein:

$$K\_NENN_1 = (stg_1 - stg_2)$$

$$K\_NENN_2 = -n_{21} + n_{11} + (stg_2 - stg_1) * u_1$$

$$K\_NENN_3 = (pwm_1 * stg_2 - pwm_2 * stg_1)$$

$$K\_NENN_4 = pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u_1 - n_{11})$$

Abstract Of The Disclosure

An [The present invention relates to an] electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals, a setpoint value being specifiable to the control unit, and the control unit emitting corresponding PWM control signals to the semiconductor output stages; a motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value[,] being stored in the control unit, and the derived nominal operating speed being able to be compared to the actual speed of the motor[, and if]. If a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages [is/are able to] can be switched off. The derivation of the nominal operating speed for the predefined setpoint value is facilitated by a three-dimensional characteristics field determined by four coordinate points.

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[Figure 1:

sollv = setpointv

ab = off

ist = actual]

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New specification part

(replace pp. 1 and 2 of the original specification)

ELECTRONICALLY COMMUTATABLE MOTOR

Background Information

The present invention relates to an electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals, a setpoint value being specifiable to the control unit, and the control unit emitting corresponding PWM control signals to the semiconductor output stages; a motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value, being stored in the control unit, and the derived nominal operating speed being able to be compared to the actual speed of the motor, and if a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages is/are able to be switched off.

Such a motor is known from the German Patent 198 04 874 A1. In that case, the PWM control signals are established in their pulse width by the input of the setpoint value. The comparison of the nominal operating speed, which is assigned to the setpoint value, to the actual speed is used during the continuous running operation for detecting sharp increases of the setpoint value acting from outside, in order to set the pulse width only gradually to the new value. Since the motor characteristic curve changes as a function of the motor

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load and the setpoint value, it requires a considerable expenditure of memory in the control unit to ascertain the allocated nominal operating speed for the comparison to the actual speed, i.e. for the monitoring of the motor.

To store the characteristic-curve data of a motor in a memory of the control unit and to use the characteristic-curve data for deriving an operating value is also known from the U.S. Patent 5,901,286 and from EP-A 0 886 057. In that case, as a rule, a characteristics field having a plurality of value pairs is used, from which the desired nominal operating value can be derived by interpolation onto a third coordinate. However, this requires a considerable expenditure of memory, particularly when the load of the motor also changes.

The object of the present invention is to provide a motor of the type mentioned at the outset with simple data in the control unit, which, with minimal expenditure, for a predefined load, significantly simplifies the derivation of the nominal operating speed corresponding to a predefined setpoint value.

This objective is achieved according to the present invention, in that the motor characteristic curve is stored as a characteristics field having four three-dimensional corner points; in the x-axis, the limiting values of the supply voltage, and in the z-axis, the limiting values of the PWM control signals determine the operating speeds of the four corner points of the characteristics field for a predefined, constant load; and the connecting lines between the corner points of the characteristics field permit the formation of a grid from

which, for an existing supply voltage and a PWM control signal corresponding to the predefined setpoint value, the allocated nominal operating speed is derivable for the comparison with the measured actual speed.

In this context, advantage is taken of the fact that in many cases, the motor is always loaded with the same consumer, such as in the case of a fan drive. The four.....

sought nominal operating speed (in the y-direction).

Depending upon the use of the motor, according to a further embodiment, the four corner points of the characteristics field may be determined for a predefined motor load. The motor can then be designed in a simple manner for a different load, i.e. consumer.

In this context, according to one refinement, the comparison between the nominal operating speed and the actual speed is able to be carried out continually during the continuous running of the motor or repeated at time intervals.

The setpoint value may be specifiable manually in a simple manner using a potentiometer, the control unit being able to be supplied with a more or less large setting signal which is used for the emission of allocated PWM control signals for the semiconductor output stages. In addition, using this setting signal, the allocated nominal operating speed may be derived on the basis of the stored motor characteristic curve and utilized for the comparison with the actual speed of the motor arising. The actual speed of the motor may be detected in different ways which are also known.

For the comparison of the nominal operating speed and the actual speed, the control unit is preferably assigned a comparator unit which, by preference, is integrated into the control unit.

So that the overload protection does not react to short interference pulses of the actual-speed measurement, one embodiment provides for the control unit and/or the semiconductor output stages to be switched off in a time-delayed manner.

If a run-up phase precedes the continuous operation of the motor, then the overload protection may be designed so that the comparison of the nominal operating speed and the actual speed is first able to be initiated and carried out after a run-up phase of a predefined duration has expired, so that an inadvertent shut-down does not occur during this operating phase. The run-up phase may be preset by the control unit, it being possible to use the amplitude of the pulses and the pulse width of the PWM control signals, as well as their commutation frequency and the like as parameters. The run-up phase of the motor is able to be initiated with the switch-on of the control unit and/or the semiconductor output stages, and/or the input of a setpoint value for the control unit.

The invention is explained more precisely with reference to an exemplary embodiment shown in the Drawing, in which:

Figure 1 shows a block diagram of the functional units of the motor; and

Figure 2 shows a characteristics field stored in the control unit.

As the block diagram according to Figure 1 shows, the motor unit includes an electronic control unit STE which is assigned a comparator unit VE. For a desired continuous operation, a correspondingly adjusted setpoint value $N_{setpointv}$ is specified to this control unit STE. Consequently, after a run-up phase, correspondingly dimensioned PWM control signals pwm are emitted to semiconductor output stages EST which energize the excitation windings of motor M according to the pulse widths of these PWM control signals pwm. An actual speed N_{actual} thereupon sets in at motor M that is detected in a

known manner and supplied as a signal to a comparator unit VE which may be integrated into control unit STE. Stored in control unit STE is a motor characteristic curve which allows the derivation of a nominal operating speed n_x for each setpoint value $N_{setpointv}$. This nominal operating speed n_x is obtained more or less exactly in the case of the predefined setpoint value $N_{setpointv}$ if control unit STE, semiconductor output stages EST and motor M are operating correctly, and no conditions exist which lead to a drop in actual speed N_{actual}.

Nominal operating speed n_x, like actual speed N_{actual}, is supplied to comparator unit VE, and a speed deviation ΔN is ascertained. If actual speed N_{actual} is more than a predefined or predefinable speed deviation ΔN below expected nominal operating speed n_x, then a fault exists which can lead to an overload during continuous operation. Therefore, comparator unit VE generates a switch-off signal AB with which control unit STE and/or semiconductor output stages EST can be switched off, as the contacts off in the electric circuit of supply voltage U_{batt} indicate.

If setpoint value $N_{setpointv}$ is changed, then PWM control signals pwm, and therefore actual speed N_{actual} of motor M change, as well. A correspondingly new nominal operating speed n_x is supplied to comparator unit VE, and the comparison is carried out in the same manner for the new continuous operation with altered speed.

The switch-off of control unit STE and/or of semiconductor output stages EST may also be initiated in a delayed fashion, in order to suppress spurious peaks in the derived and detected speed values.

Permissible speed deviation ΔN may also be made a function of the magnitude of predefined setpoint value

$N_{setpointv}$ and the existing magnitude of supply voltage u_x. The comparison by comparator unit VE may be carried out continually during the continuous operation, or repeated at time intervals. In addition, the overload protection by the comparison and the shutdown may first be switched to effective after reaching the nominal operating speed specified by the setpoint value, i.e. after a predefined or predefinable run-up time has expired. In this context, the run-up time may be started with the switching-on, that is to say, with the feeding of supply voltage u_x to control circuit STE and/or to semiconductor output stages EST, and/or with the application of a predefined setpoint value $N_{setpointv}$ to control unit STE.

Nominal operating speed n_x, derived and calculated by control unit STE, is a function not only of existing supply voltage u_x with its limiting values u_1 and u_2, but also of stored speeds n_{11}, n_{12}, n_{21}, n_{22} of the corner points of characteristics field KF, as the specification $n_x=f(N_{setpointv}, u_1, u_2, n_{11}, n_{12}, n_{21}, n_{22})$ in the Figure indicates, and as is clarified later.

As the three-dimensional characteristics field KF according to Figure 2 shows, the voltage range from U_{max} to U_{min} is plotted in the x-direction, while the pulse width from pwm_{min} to pwm_{max} extends in the z-direction. In the exemplary embodiment, U_{max} = 13V and U_{min} = 8V are selected, and the pulse width has a range from pwm_{min} = 60% to pwm_{max} = 100%. For the smallest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds of n_{11} = 50 min^{-1} and n_{21} = 1800 mm^{-1} result, while for the greatest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds n_{12} = 150 min^{-1} and n_{22} = 2900 min^{-1} result. These nominal operating speeds n_{11} to n_{22} define the four corner points P1 to P4 in three-dimensional characteristics field KF. The connecting lines between corner points n_{11} and n_{21}, n_{11}

and n_{12}, n_{21} and n_{22}, and n_{12} and n_{22}, respectively, permit the formation of a grid which, for existing supply voltages U_x and pulse width pwm_x corresponding to a setpoint value, allows the derivation of allocated nominal operating speeds n_x on straight line $n1_x - n2_x$. Thus, given a supply voltage of $U_x = 10.5V$ and a pulse width of approximately 87%, a nominal operating speed of approximately 1800 min^{-1} can be interpolated from characteristics field KF.

This characteristics field KF is valid for a specific motor for a predefined, constant load. For another load, a characteristics field KF valid for it can be stored in control unit STE.

As the three-dimensional characteristics field KF according to Figure 2 shows, supply voltage u_x having the voltage range from smallest supply voltage $u_1 = 8V$ to greatest supply voltage $u_2 = 13V$ is plotted in the x-direction. In the z-direction, pulse width pwm of the PWM control signals is predefined, which may extend from minimal pulse width $pwm_1 = 60\%$ to maximum pulse width $pwm_2 = 100\%$. Given a preselected load of the motor, four limit operation cases are ascertained with u_1 and pwm_1, u_1 and pwm_2, u_2 and pwm_1, as well as u_2 and pwm_2, which lead to nominal operating speeds $n_x = n_1$, n_{12}, n_{21} and n_{22}, and consequently define characteristics field KF according to Figure 2.

If motor M is loaded with a different load, then a similar characteristics field KF results having new nominal operating speeds n_{11}, n_{12}, n_{21} and n_{22}.

The following values result for characteristics field KF of an exemplary embodiment shown in Figure 2:

$n_{11} = 50\ min^{-1}$ at $u_1 = 8V$ and $pwm_1 = 60\ \%$

n_{12} = 150 min^{-1} at u_2 = 13V and pwm_1 = 60 %
n_{21} = 1800 min^{-1} at u_1 = 8V and pwm_2 = 100 %
n_{22} = 2900 min^{-1} at u_2 = 13V and pwm_2 = 100 %

Characteristics field KF can be represented as a grid, the connecting lines between corner points n_{11} and n_{12}, and n_{21} and n_{22}, respectively, as well as n_{11} and n_{22}, and n_{12} and n_{22}, respectively, specifying the gridding, and as is shown, for an existing supply voltage u_x, permitting the derivation of allocated nominal operating speed n_x in the case of existing PWM control signal p_x. PWM control signal pwm_x is allocated to predefined setpoint value $N_{setpointv}$.

As grid line nx_1 - nx_2 shows, in the case of u_x = 10.5V and a pulse width of $pwm_x \approx 87.5\%$, the derivation of nominal operating speed n_x leads to a value of approximately 1800 min^{-1}.

To calculate nominal operating speed n_x allocated to a setpoint value $N_{setpointv}$, one proceeds as follows:

$$stg1 = \frac{n_{12} - n_{11}}{u_2 - u_1} \qquad stg2 = \frac{n_{22} - n_{21}}{u_2 - u_1}$$

$$n_{1x} = n_{11} + stg_1 * (u_x - u_1)$$
$$n_{2x} = n_{21} + stg_2 * (u_x - u_1)$$

$$stg_3 = \frac{n_{2x} - n_{1x}}{pwm_2 - pwm_1} = \frac{n_{21} - n_{11} + (stg_2 - stg_1) * (u_x - u_1)}{pwm_2 - pwm_1}$$

Therein:

stgi -

stg2 -

stgs3 -

$$\boxed{n_x = n_{1x} + stg_3 * (pwm_x - pwm_1)}$$

Since computer-internally, work is not done with the speed, but rather with its reciprocal value, the above equation for calculating surface point n_x must be changed around accordingly. With $T_x = a/n_x$, it follows that:

$$\frac{a}{T_x} = n_{1x} + stg_3 * (pwm_x - pwm_1)$$

$$T_x = \frac{a * (pwm_1 - pwm_2)}{(((stg_1 - stg_2) * u_x - n_{21} + n_{11} + (stg_2 - stg_1) * u_1) * pwm_x + (pwm_1 * stg_2 - pwm_2 * stg_1) * u_x + pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u}$$

In the formula above, only supply voltage U_x and the pulse width of output-stage control pwm_x are variable. The remaining factors may be stored as fixed parameters in the ROM or EEPROM. Following is once again the same formula with the variable names used in the program code.

$$v\_tx = \frac{K\_ZAEHL_1}{\left(\left(K\_NENN_1 * v\_ubat + K\_NENN_2\right) * v\_pwm\_endst + K\_NENN_3 * v\_ubat + K\_NENN_4\right)}$$

During the programming at the rear end of the assembly line, the corresponding parameters can now be transferred from the test stand into the EEPROM of the motor control

$$K\_NENN_1 = \left(stg_1 - stg_2\right)$$

$$K\_NENN_2 = -n_{21} + n_{11} + \left(stg_2 - stg_1\right) * u_1$$

$$K\_NENN_3 = \left(pwm_1 * stg_2 - pwm_2 * stg_1\right)$$

$$K\_NENN_4 = pwm_1 * \left(n_{21} - u_1 * stg_2\right) + pwm_2 * \left(stg_1 * u_1 - n_{11}\right)$$

New Patent Claim 1

An electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages (EST) by an electronic control unit (STE) with the aid of PWM control signals (PWM_{end}), a setpoint value ($N_{setpointv}$) being specifiable to the control unit (STE), and the control unit (STE) emitting corresponding PWM control signals (PWM) to the semiconductor output stages (EST); a motor characteristic curve, from which an assigned nominal operating speed (n_x) is derivable for the setpoint value ($N_{setpointv}$), being stored in the control unit (STE), and the derived nominal operating speed (n_x) being able to be compared to the actual speed (N_{actual}) of the motor (M), and if a predefinable or predefined speed difference (ΔN) between the nominal operating speed (n_x) and the actual speed (N_{actual}) is exceeded, the control unit (STE) and/or the semiconductor output stages (EST) is/are able to be switched off,
wherein the motor characteristic curve is stored as a characteristics field (KF) having four three-dimensional corner points (x, y, z); in the x-axis, the limiting values (u_1 and u_2) of the supply voltage, and in the z-axis, the limiting values (pwm_{min} and pwm_{max}) of the PWM control signals determine the operating speeds (n_{11}, n_{12}, n_{21} and n_{22}) of the four corner points of the characteristics field (KF) for a predefined, constant load; and the connecting lines (n_{11}-n_{12}; n_{12}-n_{21}; n_{21}-n_{22}; n_{22}-n_{11}) between the corner points of the characteristics field (KF) permit the formation of a grid, from which, for an existing supply voltage (u_x) and a PWM control signal (pwm_x) corresponding to the predefined setpoint value ($N_{setpointv}$), the allocated nominal operating speed (n_x) is derivable for the comparison to the measured

actual speed (N_{actual}).

2. The electronically commutatable motor as recited in Claim 1,
wherein the four corner points of the characteristics field (KF) are determined for a predefined motor load.

3. The electronically commutatable motor as recited in Claim 1 or 2,
wherein the comparison between the nominal operating speed (n_x) and the actual speed (N_{actual}) is able to be carried out continually during the continuous operation of the motor, or repeated at time intervals.

4. The electronically commutatable motor as recited in one of Claims 1 through 3,
wherein the setpoint value ($N_{setpointv}$) is specifiable manually using a potentiometer.

5. The electronically commutatable motor as recited in one of Claims 1 through 4,
wherein, for the comparison of the nominal operating speed (n_x) and the actual speed (N_{actual}), the control unit (STE) is assigned a comparator unit (VE) which is preferably integrated into the control unit (STE).

6. The electronically commutatable motor as recited in one of Claims 1 through 5,
wherein the switch-off (off) of the control unit (STE) and or of the semiconductor output stages (EST) is carried out in a time-delayed manner.

7. The electronically commutatable motor as recited in one of Claims 1 through 6,
wherein the comparison of the nominal operating speed (n_x) and the actual speed (N_{actual}) is able to be initiated and carried out only after a run-up phase of a predefined

duration has expired.

8. The electronically commutatable motor as recited in Claim 7,
wherein the run-up phase is able to be initiated with the switching-on of the control unit (STE) and/or the semiconductor output stages (EST), and/or the input of a setpoint value ($N_{setpointv}$).

Abstract

The present invention relates to an electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals, a setpoint value being specifiable to the control unit, and the control unit emitting corresponding PWM control signals to the semiconductor output stages; a motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value, being stored in the control unit, and the derived nominal operating speed being able to be compared to the actual speed of the motor, and if a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages is/are able to be switched off. The derivation of the nominal operating speed for the predefined setpoint value is facilitated by a three-dimensional characteristics field determined by four coordinate points.

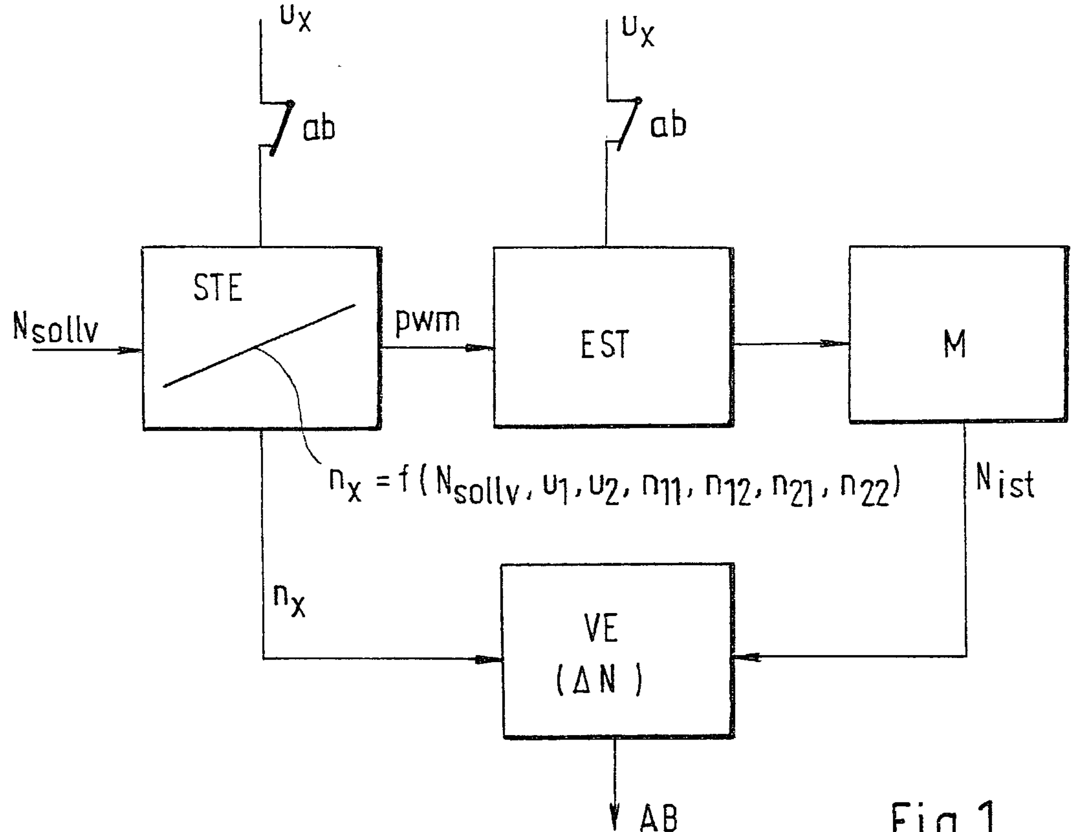
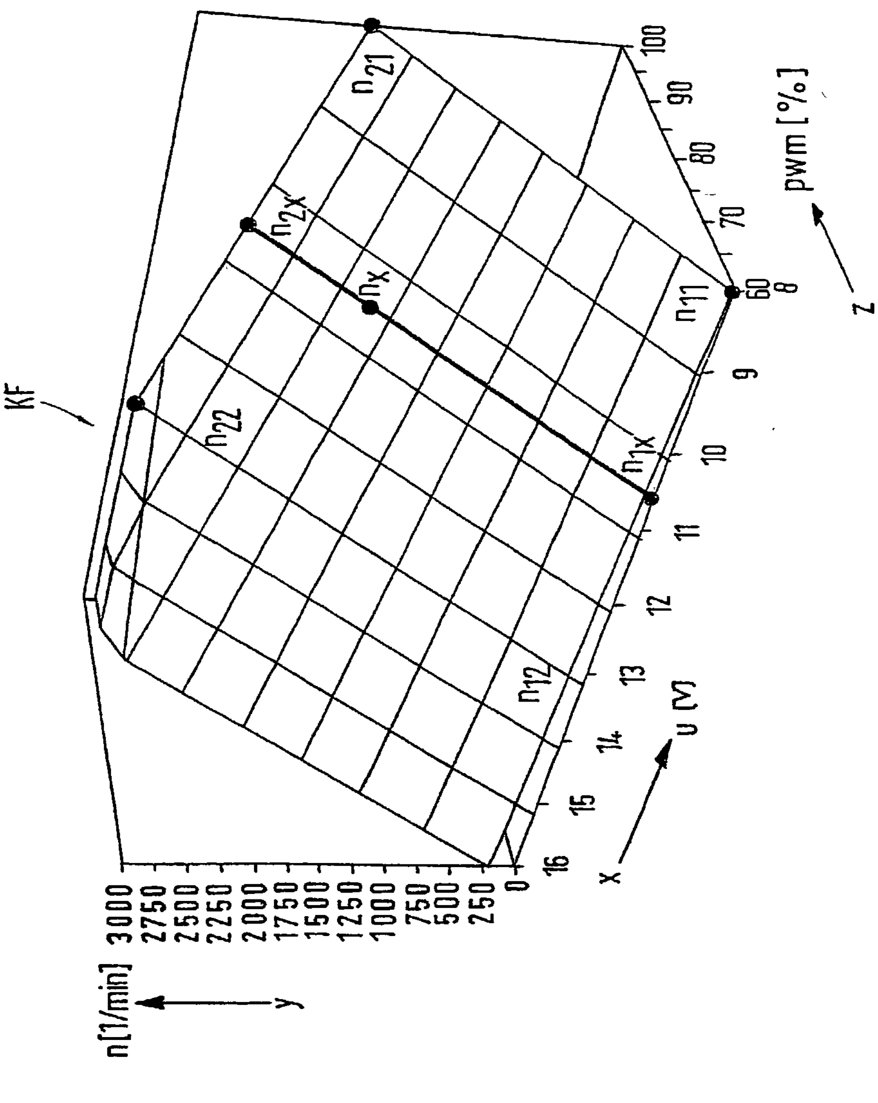

u_x
ab
u_x
ab
N_{sollv}
STE
pwm
EST
M
$n_x = f(N_{sollv}, u_1, u_2, n_{11}, n_{12}, n_{21}, n_{22})$
N_{ist}
n_x
VE
(ΔN)
AB

Fig.1

Fig.2


KF
n21
n2x
nx
n22
n11
n1x
n12
pwm [%]
100
90
80
70
60
8
9
10
11
12
13
14
15
16
u [V]
x
z
y
n[1/min]
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0

[10191/2225]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **ELECTRONICALLY COMMUTATABLE MOTOR**, the specification of which was filed as International Application No. **PCT/DE00/03194** on September 14, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

~~9L5966132274~~

PRIOR FOREIGN APPLICATION(S)

Number	Country filed	Day/month/year	Priority Claimed Under 35 USC 119
199 44 196.0	Fed. Rep. of Germany	15 September 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

1-10

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3-00

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